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N91-27290

Program 5 Measurements and Mechanisms of Localized Aqueous Corrosion in
Aluminum-Lithium-Copper Alloys

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Objectives

The objective of this research is to characterize the localized corrosion and stress corrosion crack initiation behavior of Al-Li-Cu alloy 2090 in aqueous environments, and to gain an understanding of the role of local corrosion and occluded cell environments in the mechanisms of pitting and stress corrosion crack initiation and early-stage propagation.

Mechanisms of Localized Corrosion
in Alloys 2090 and X2095

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This report includes summary information of electrochemical aspects of stress corrosion cracking in alloy 2090 and an introduction to the work to be initiated on the new X2095 (Weldalite) alloy system.

Stress corrosion cracking (SCC) was studied in both S-T and L-T orientations in alloy 2090. A constant load TTF test was performed in several environments with a potentiostatically applied potential. In the same environments the electrochemical behavior of phases found along subgrain boundaries was assessed. It was found that rapid failure due to SCC occurred when the following criteria was met: $E_{BR,T1} < E_{applied} < E_{BR, matrix phase}$. Although the L-T orientation is usually considered more resistant to SCC, failures in this orientation occurred when the stated criteria was met. This may be due to the relatively isotropic geometry of the subgrains which measure approximately 15-25 μm in diameter.

Initial studies of alloy X2095 will include electrochemical characterization of three compositional variations each at three tempers. The role of T_1 dissolution in SCC behavior will be addressed using techniques similar to those used in the research of 2090 described above. SCC susceptibility will also be studied using alternate immersion facilities at Reynolds Metals Corporation. Pitting will be investigated in terms of stability, role of precipitate phases and constituent particles, and as initiation sites for SCC.

In all research endeavors attempts will be made to link electrochemistry to microstructure. Previous work on 2090 will provide a convenient basis for comparison since both alloys contain T_1 precipitates but with different distributions. In 2090 T_1 forms preferentially on subgrain boundaries whereas in X2095 the microstructure appears to be more homogeneous with finer T_1 particles. Another point for comparison is the δ' strengthening phase found in 2090 but absent in X2095.

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**Co-sponsor : Reynolds Metals Corporation
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OUTLINE OF PRESENTATION

I. Completed work on alloy 2090

- A. Summery of results by R.G. Buchheit**
- B. New data and results**

II. Proposed project on X2095 alloys

- A. Materials**
- B. Initial objectives**

**The Role of Anodic Dissolution in the SCC
of Alloy 2090**

Graduate research assistant : Rudy Buchheit

Undergraduate assistant : Doug Wall

PREVIOUS WORK

(presented earlier by R. G. Buchheit)

- (1) Study the electrochemical behavior of phases present along the subgrain boundaries.**
- (2) Evaluate SCC susceptibility in S-T direction as a function of applied potential.**
- (3) Correlate electrochemical parameters to SCC behavior.**

EXPERIMENTAL

Environments:

0.6M NaCl

0.1M NaCl + 0.1M Na₂CrO₄

0.6M NaCl + 0.1M Li₂CO₃

Potentiodynamic polarizations:

<u>Phase of Interest</u>	<u>Model</u>
α -Al	SHT 2090
Cu-depleted zone	1100 Aluminum
T ₁	cast ingot

Time-to-failure testing:

Loading axis in S-T direction

Constant load at 62%YS

Smooth bar tensile samples

Potentiostatic anodic polarization

RESULTS OF ELECTROCHEMICAL TESTING

0.6M NaCl

<u>Material</u>	<u>$E_{\text{corr}}(\text{V}_{\text{SCE}})$</u>	<u>$E_{\text{br}}(\text{V}_{\text{SCE}})$</u>	<u>$i_{\text{pass}}(\mu\text{A}/\text{cm}^2)$</u>
α -Al	-0.729	-0.731	not measured
Cu-DZ	-0.840	-0.749	0.024
T ₁	-1.096	-0.723	400

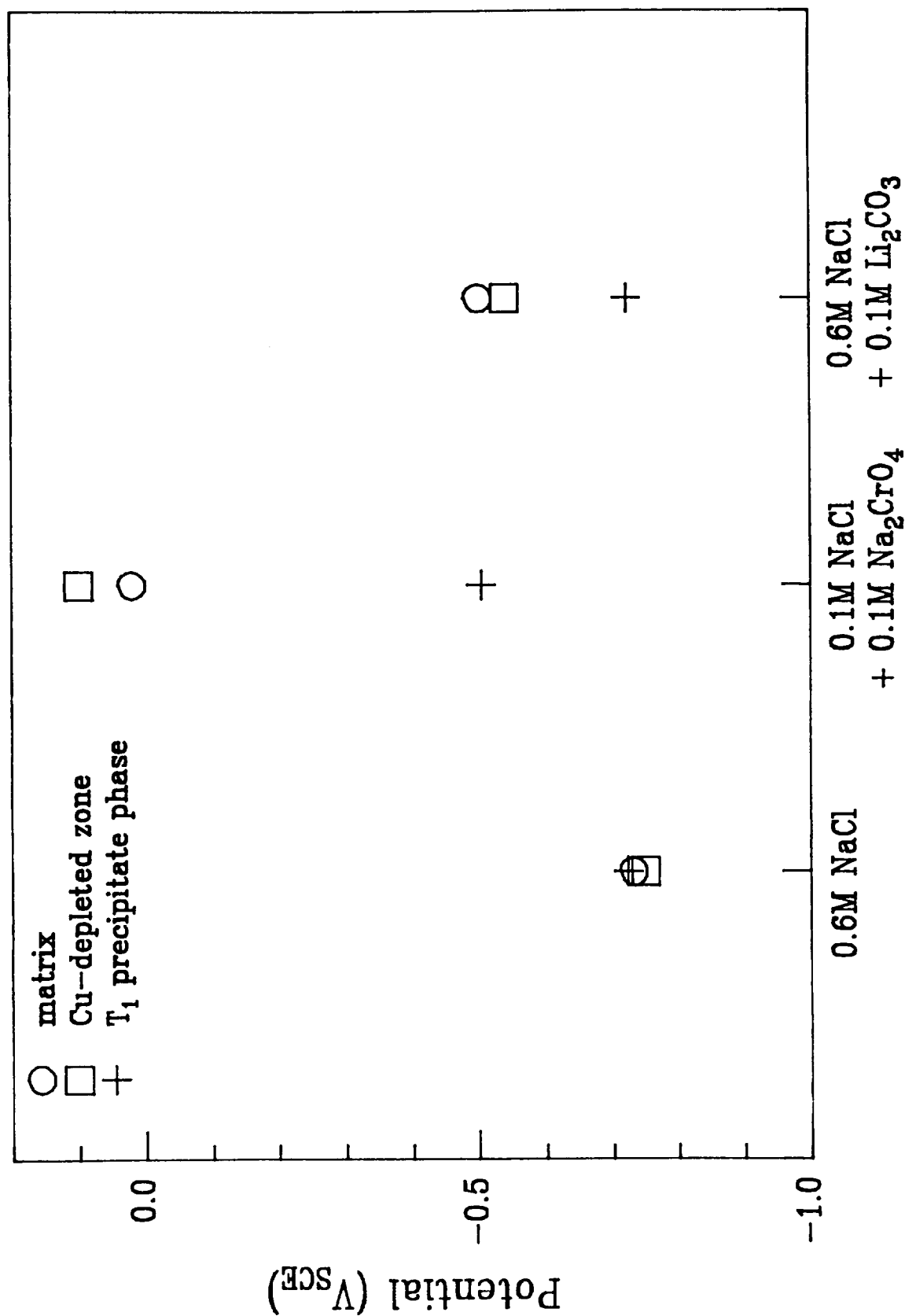
0.1M NaCl + 0.1M Na₂CrO₄

<u>Material</u>	<u>$E_{\text{corr}}(\text{V}_{\text{SCE}})$</u>	<u>$E_{\text{br}}(\text{V}_{\text{SCE}})$</u>	<u>$i_{\text{pass}}(\mu\text{A}/\text{cm}^2)$</u>
α -Al	-0.751	+0.020	3.7
Cu-DZ	-0.920	+0.100	4.0
T ₁	-1.195	-0.504	80

0.6M NaCl + 0.1M Li₂CO₃

<u>Material</u>	<u>$E_{\text{corr}}(\text{V}_{\text{SCE}})$</u>	<u>$E_{\text{br}}(\text{V}_{\text{SCE}})$</u>	<u>$i_{\text{pass}}(\mu\text{A}/\text{cm}^2)$</u>
α -Al	-1.600	-0.500	2.0
Cu-DZ	-1.633	-0.540	0.44
T ₁	-1.143	-0.721	250

Breakaway Potentials of Subgrain Boundary Phases



Time-to-Failure Results for Samples in 0.6M NaCl

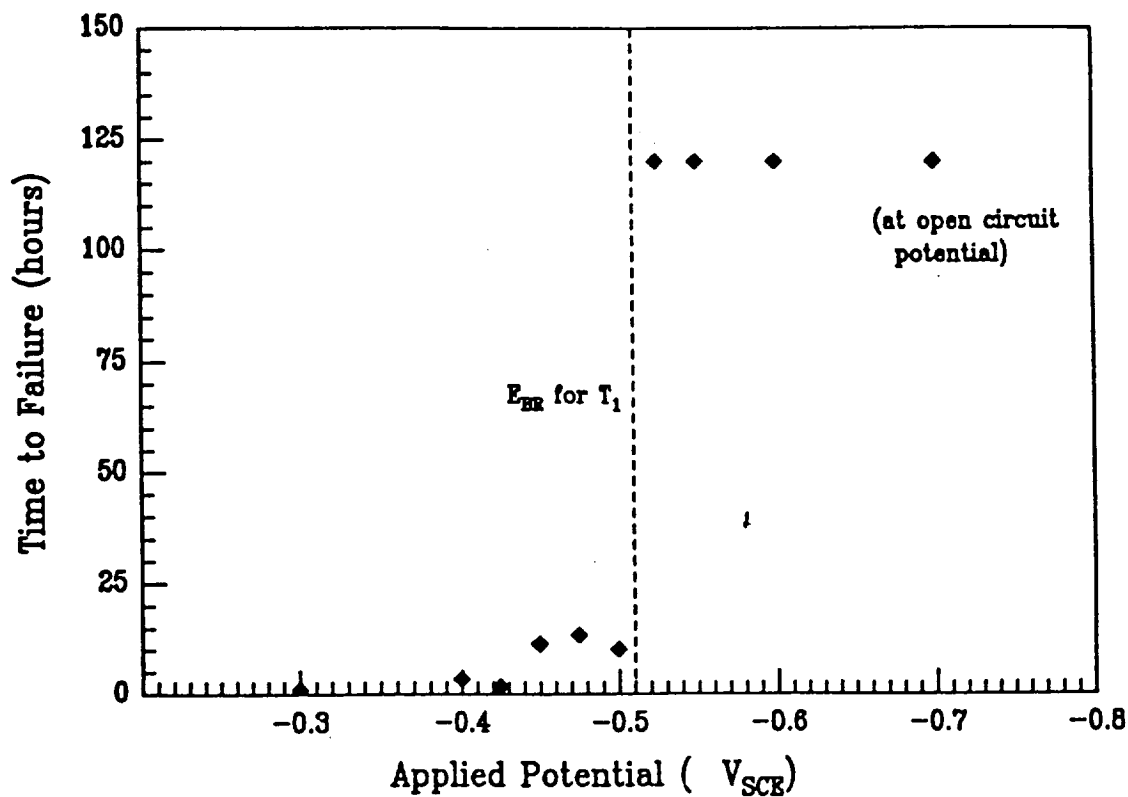
<u>Applied Potential (Vsce)</u>	<u>Time to Failure (Days)</u>
-0.650	1 @ > 5 *
-0.700	1 @ > 5 *
-0.715	2 @ > 45 +
-0.720 (E_{corr})	3 @ > 45 +
-0.725	1 @ > 5 *
-0.730	1 @ > 5 *
-0.900	1 @ > 5 *
-1.150	2 @ > 45 +

1 @ > 5 : read one specimen did not fail after 5 days

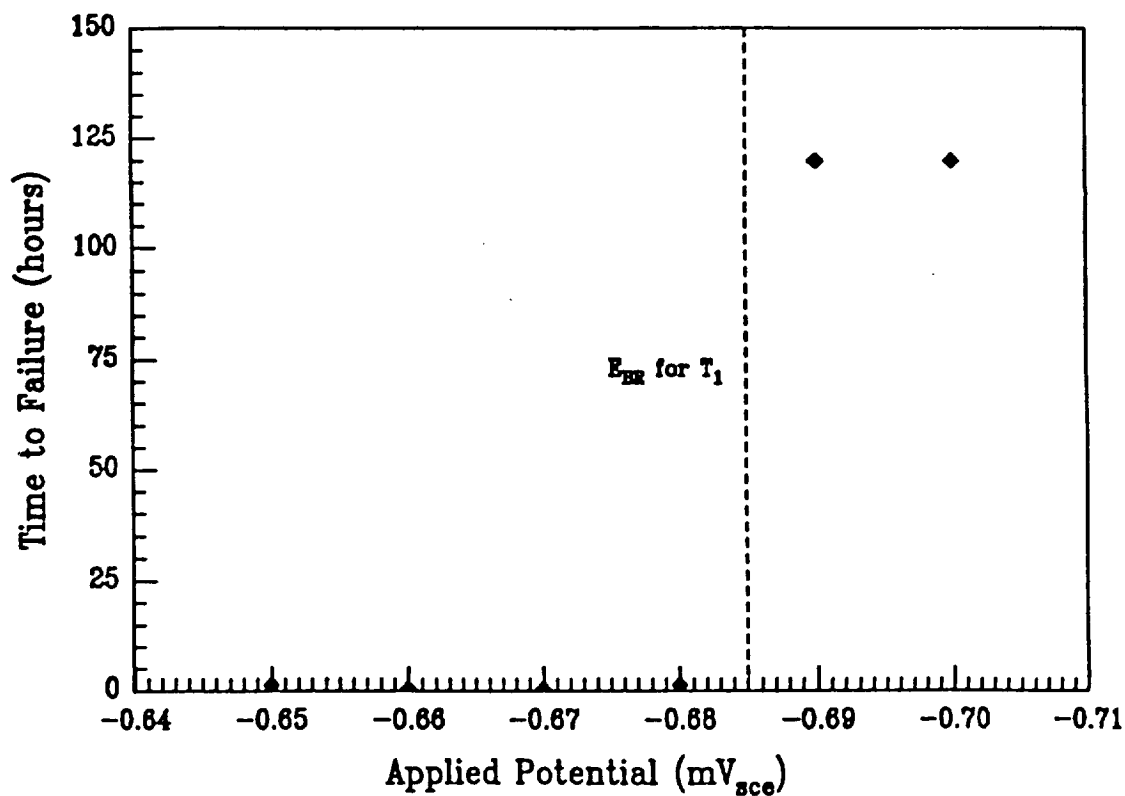
* per ASTM G49

+ per static load technique

TTF Results for samples in 0.1M NaCl + 0.1M Na₂CrO₄



TTF Results for samples in 0.6M NaCl + 0.1M Li₂CO₃



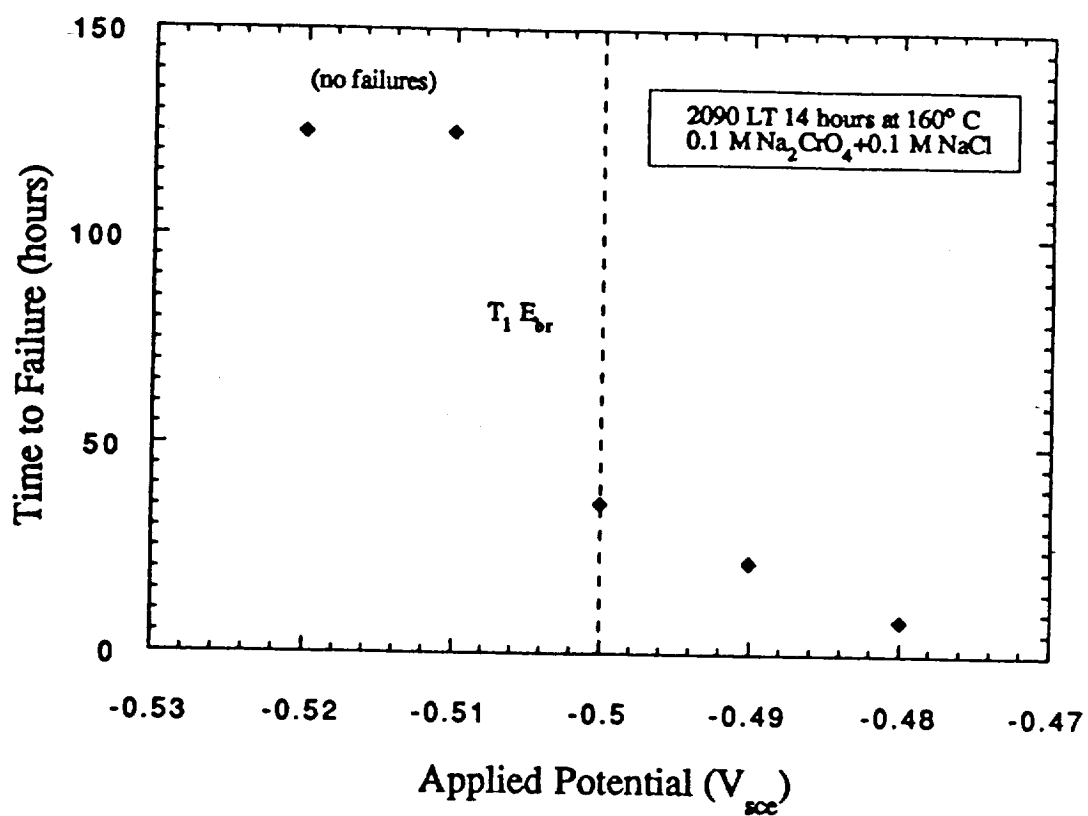
CONCLUSIONS

- (1) In the S-T direction rapid failure due to SCC occurs if the following criteria is met:

$$E_{BR, T1} < E_{\text{applied}} < E_{BR, \alpha-Al}$$

- (2) In 0.6M NaCl the criteria is not met since $E_{BR, T1} \approx E_{BR, \alpha-Al}$ and no rapid failures occur.
- (3) In NaCl solution with either Li_2CO_3 or Na_2CrO_4 added there exists a potential window in which the criteria can be met and rapid failures occur.

Results for L-T samples in 0.1M NaCl + 0.1M Na₂CrO₄



CONCLUSIONS

- (1) Rapid failure due to SCC in the L-T direction occurs under the same conditions as seen for the S-T orientation:

$$E_{BR, T1} < E_{applied} < E_{BR, \alpha-Al}$$

- (2) Since the crack appears to follow subgrain boundaries, embrittlement in the L-T orientation may occur due to the equiaxed subgrains in the 2090 plate.
- (3) In the environments investigated the dissolution of the T_1 phase appears to be the primary mechanism for SCC due to anodic dissolution.

**Mechanisms of Localized Corrosion
in Alloy X2095 and Compositional Variations**

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MATERIALS

X2095, 3 tempers

Compositional variations : RX820, RX821, 3 tempers each

Composition of X2095

<u>Element</u>	<u>Percentage</u>
Al	Balance
Cu	3.9-4.6
Li	1.0-1.6
Mg	0.25-0.6
Ag	0.25-0.6
Si	0.12 Max
Fe	0.15 Max
Mn	0.10 Max
Zn	0.25 Max
Zr	0.04-0.18
Ti	0.10 Max
Others, each	0.05 Max
Others, total	0.15 Max

MATERIALS (PROPERTIES)

For X2095 in T8 condition

<u>Direction</u>	<u>UTS (ksi)</u>	<u>TYS(ksi)</u>	<u>EL(%)</u>
L	90.0	86.0	9.3
L-T	89.2	82.3	9.6
45 deg.	80.6	73.6	14.3

<u>Direction</u>	<u>K_{IC}(w=1")</u>	<u>K_R^{max}(w=6")</u>	<u>K_C(16"wide)</u>
L-T	28.4	62.0	69.7
T-L	24.3	56.0	43.4

No δ' (Al₃Li)

T₁ (Al₂CuLi) is primary strengthening phase,
distribution is more homogeneous than in 2090

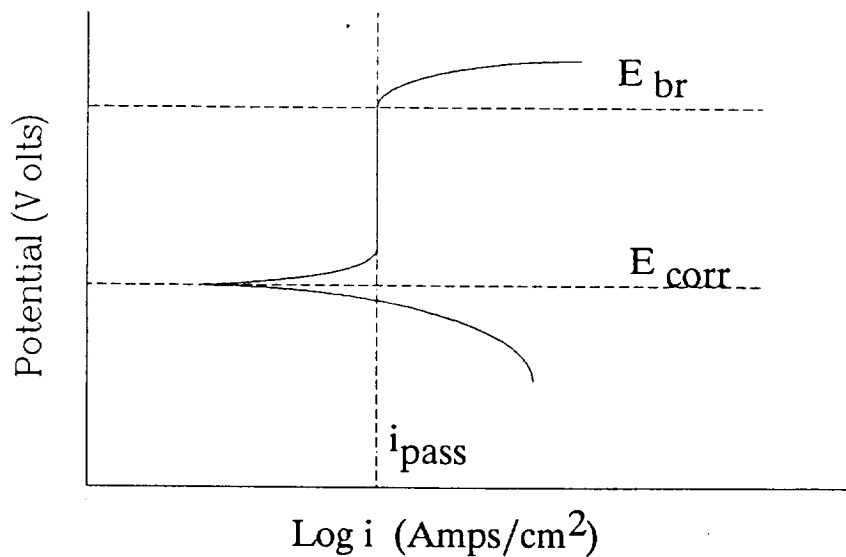
TEMPERS

- (1) 290°F/20 hrs
- (2) 290°F/30 hrs
- (3) 290°F/20 hrs + ramp to 400°F at 50°F/hr +
400°F/5 min

PROPOSED WORK - ELECTROCHEMISTRY, PITTING

- (1) Examine parameters : passive current density
open circuit potential
breakaway potential

each as a function of composition and temper.



- (2) Are there preferential sites for pit initiation?
Inclusions?
 T_1 precipitates?
- (3) Will pitting or intergranular corrosion be observed below the breakaway potential of the matrix phase due to T_1 dissolution?

Will such pitting be arrested once exposed T_1 is depleted?

PROPOSED WORK - SCC BEHAVIOR

- (1) Does anodic dissolution play a key role in crack growth?**
- (2) Will homogeneous T_1 distribution result in better SCC resistance?**
- (3) Is there a Cu depleted zone and what contribution does it have to SCC?**
- (4) Will the absense of δ' affect SCC behavior?**

Alternate Immersion testing at Reynolds Corporation.

Constant load TTF testing w/applied potentials.

Comparison of behavior to alloy 2090.